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ORIGINAL

The Effectiveness of Augmented Reality-Assisted E-Module in Improving Students Digital Literacy in High School Biology Learning

La efectividad del módulo electrónico asistido por realidad aumentada para mejorar la alfabetización digital de los estudiantes en el aprendizaje de biología en la escuela secundaria

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ABSTRACT

This study aims to determine the effectiveness of augmented reality (AR)-assisted e-modules to improve digital literacy for students in high school Biology learning. This study uses a quantitative method with a Quasi Experimental non-equivalent control group design . The respondents in this study were high school students in Aceh Province, Indonesia, as many as 96 students consisting of 49 students in the control group and 47 students in the treatment group. Data collection uses a digital literacy questionnaire with the Likert Scale through pre-test and post-test activities. Improving students' digital literacy using N Gain criteria. The data normality test uses the Kolmogorov-Smirnov Test. Data homogeneity test uses the Levene Test. If the data has been distributed normally and homogeneously, then the ANCOVA test continues. Data analysis uses SPSS version 24.0. The test results are used as the basis for making hypothesis decisions. The results showed that the corrected average score of digital literacy in the control class (68,465) was lower than the average score of digital literacy in the treatment class (78,877). Based on ANCOVA analysis, students' digital literacy obtained a significant score of 0,000 or a p value of <0,05, so it can be said that there is a difference in students' digital literacy in the control and treatment classes. This means that learning through AR-assisted e-modules using the PBL model has a better influence on students' digital literacy than PBL alone. Further research can be carried out by implementing AR-assisted e-modules at each school level to determine students' critical thinking skills, creativity, and learning outcomes.

Keyword: E-Modul; Augmented Reality; Literacy Digital; Problem Based Learning.

RESUMEN

Este estudio tiene como objetivo determinar la efectividad de los módulos electrónicos asistidos por realidad aumentada (AR) para mejorar la alfabetización digital de los estudiantes en el aprendizaje de biología de la escuela secundaria. Este estudio utiliza un método cuantitativo con un diseño de grupo control cuasi experimental no equivalente. Los encuestados en este estudio eran estudiantes de secundaria en la provincia de Aceh, Indonesia, hasta 96 estudiantes, de los cuales 49 eran estudiantes en el grupo de control y 47 estudiantes en el grupo de tratamiento. La recolección de datos utiliza un cuestionario de alfabetización digital con la Escala Likert a través de actividades pre-test y post-test. Mejorar la alfabetización digital del alumnado utilizando criterios N Gain. La prueba de normalidad de los datos utiliza la prueba de Kolmogorov-Smirnov y la prueba de homogeneidad de datos utiliza la prueba de Levene. Si los datos se han distribuido de forma normal y homogénea, la prueba ANCOVA continúa. El análisis de los datos utiliza el programa SPSS

versión 24.0. Los resultados de la prueba se utilizan como base para tomar decisiones de hipótesis. Los resultados mostraron que la puntuación media corregida de alfabetización digital en la clase de control (68,465) fue inferior a la puntuación media de alfabetización digital en la clase de tratamiento (78,877). Con base en el análisis de ANCOVA, la alfabetización digital de los estudiantes obtuvo un puntaje significativo de 0,000 o un valor de p de <0,05, por lo que se puede decir que existe una diferencia en la alfabetización digital de los estudiantes en las clases de control y tratamiento. Esto significa que el aprendizaje a través de módulos electrónicos asistidos por RA utilizando el modelo ABP tiene una mayor influencia en la alfabetización digital de los estudiantes que el ABP por sí solo. Se pueden llevar a cabo más investigaciones mediante la implementación de módulos electrónicos asistidos por RA en cada nivel escolar para determinar las habilidades de pensamiento crítico, la creatividad y los resultados de aprendizaje de los estudiantes.

Palabra clave: E-Modul; Realidad Aumentada; Alfabetización Digital; Aprendizaje Basado en Problemas.

INTRODUCTION

The rapid development of technology and information requires modifications in the field of education. Students must have the knowledge, abilities, and dispositions necessary to engage and adapt competently to rapidly evolving job prospects.[1] An important skill in the digital era is digital literacy. Digital literacy includes the capacity to utilize digital technology to search, access,[2,3,4,5,6] managing, integrating, and evaluating information,[3,7] enabling the safe and appropriate dissemination of analytical results to the public.[3,4,7,8] Digitally literate individuals not only have the ability to operate digital technology devices,[9,10] but it also requires knowledge, skills, and attitudes to utilize digital technology effectively.[3,8,9,11] Digital technology includes software and hardware used for educational, social, and entertainment purposes.[3,11,12,13,14]

Digital literacy in education encourages lifelong learning,[15,16] improving creativity, critical thinking, and problem-solving skills,[16,17] facilitating communication, [18,19] and improving learning outcomes.[16] In the social realm, digital literacy improves social empowerment by facilitating connectivity and access to information,[20] while fostering awareness for critical analysis of information from social media.[21]

The digital literacy assessment of high school students in Pidie Regency, Aceh Province revealed an average score of 21,41 % for digital knowledge indicators, 24,09 % for skills indicators, 22,75 % for attitude indicators, and 16,68 % for behavioral indicators. The measurement results show that children's digital literacy is inadequate. The inadequate level of digital literacy is caused by the integration of technology in education that is not optimal. Certain educators fail to create interactive learning media, despite being obliged to integrate digital technology into teaching materials. The use of educational resources combined with digital technology seeks to increase digital literacy.

Independent curriculum encourages innovative learning progress that is tailored to student needs, especially in the use of digital technology. The integration of technology in education facilitates a paradigm shift, improves learning effectiveness, and offers greater communicative opportunities. Educators can improve the learning process by creating teaching resources in the format of electronic modules (e-modules). E-modules are autonomous resources that are arranged methodically and delivered in an electronic format. E-modules can use film, animation, and audio to enhance the student learning experience. E-modules are prevalent educational media that effectively meet the needs of students in achieving learning goals.[22] However, the e-modules created so far have not involved students' curiosity. The unappealing design of the e-module results in inadequate student engagement for the autonomous exploration of the topic. This affects the limited capacity of students to use digital technology for learning, thus hindering digital literacy. Students demonstrate reduced proficiency in utilizing digital devices to access, evaluate, and manage information. E-modules will be more interesting if they are designed using augmented reality (AR) technology.

Augmented reality (AR) is a technology that integrates the physical environment with virtual entities through digital devices.[23,24,25] Augmented Reality (AR) is characterized by interactivity and three-dimensional (3D) displays, allowing users to engage with real environments.[25,26,27] Augmented Reality (AR) offers many benefits for educational applications.[27,28,29,30,31] Augmented Reality has been evaluated for its potential to improve Digital Literacy,[32,33] because of its impact on learning activities and efficacy.[34] Students can leverage AR technology to overcome challenges and identify the right solutions. Students have adapted to take advantage of digital gadgets and acquire abilities related to the requirements of the contemporary technological landscape.

AR-assisted e-modules will be more effective if they are aligned with the learning model. Problem Based Learning (PBL) is a learning methodology that is suitable for the application of AR-assisted e-modules. Problem-Based Learning (PBL) is an educational framework that introduces genuine and authentic problems to be addressed.[35] Project-Based Learning (PBL) can increase students' capacity to overcome difficulties rooted in scientific phenomena seen in daily life.[36] Students are trained proficiently in problem-solving, while teachers

function as facilitators.[37,38] An investigation into the creation of e-modules utilizing the PBL paradigm has been carried out to improve problem-solving skills and self-efficacy,[39] scientific literacy,[40] collaborative competence,[41] critical thinking skills,[42] life skills[43] and creative thinking.[44] This study seeks to evaluate the efficacy of AR-assisted e-modules in improving the digital literacy of secondary school students in Biology education.

METHOD

This type of research is research *and development*. The products developed are in the form of learning tools and AR e-modules based on local potential. The development model in this study uses the development model of Lee & Owens. [45] The model consists of five stages, namely: (1) Assessment and analysis; (2) Design; (3) Development; (4) Implementation and (5) Evaluation. The stage of development can be seen in figure 1.

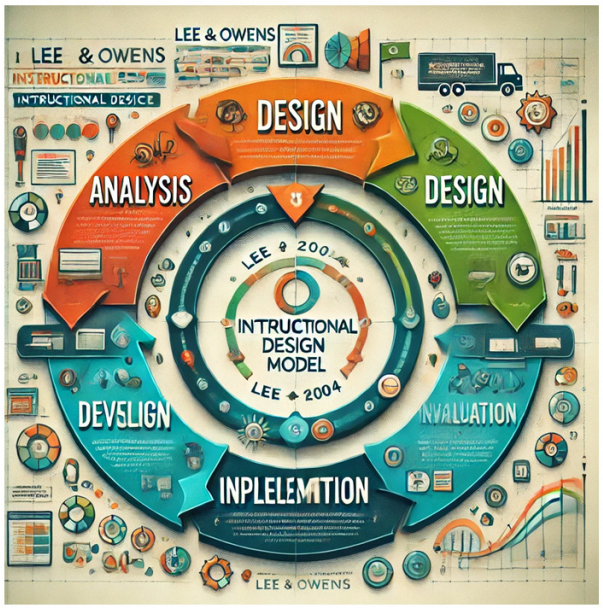

Figure 1. Lee & Owens Model Development Stage

The design stage is the stage that is carried out after obtaining information from the needs analysis and the front end. This stage results in a course design specification document (CDS). The design stages are as follows.

Determination of activity schedule

This is done to explain the project by listing the achievements, results, and development schedule of multimedia and learning tools. The following is the schedule for planning the implementation of learning development using the AR e-module (table 1).

Table 1. Schedule for Planning the Implementation of Learning Development Using the AR E-Module

Activities	Schedule
Analysis	May - July 2022
Design	August - September 2022
Development	October 2022 - January 2023
Implementation	February - May 2023
Evaluation	June 2023

Putting together a project team

The AR e-module development project team is researchers, experts in the field of Educational Technology, and information and communication technology experts from the State University of Malang.

Designing product specifications to be developed

The teaching materials developed are AR e-modules based on the local potential of Tahura Pocut Meurah Intan using PBL syntax. This stage determines the text layout, writing style, presentation theme, buttons and so on (table 2). The e-module also comes with a user manual for teachers (table 3).

Table 2. Make-up E-Module

Part	Component
Front cover	E-module identity Author and supervisor names Image illustration University Logo
The Initial Part	E-module identity Main Menu Instructions for Use Learning Outcomes and Learning Objectives
Fill	Learning objectives Material description Learning activities Camera AR Evaluation
Closing Section	Assessment guidelines Answer key Glossary Reference list
Back cover	Author bio

Table 3. Components of the AR e-Module Instruction Manual for Teachers

Part	Component
Chapter 1. Platform Specifications	Minimum specifications of the smartphone Application installation instructions
Chapter 2. App Description	Brief description of the app
Chapter 3. Learning Tools	Learning Objectives Flow (ATP) Teach Mode
Chapter 4. Local Potential of Tahura Pocut Meurah Intan	Tahura Pocut Meurah Intan Ecosystem and Its Interactions Environmental Change and Conservation of Tahura Pocut Meurah Intan

Designing the structure of learning materials to be developed in the AR E module

This stage is carried out based on curriculum analysis, learning outcomes, learning objectives flow, (ATP), teaching modules and learning objectives. The e-module is implemented with the Problem Based Learning (PBL) learning model to empower AR E module.

Perform configuration control on the design of the AR e-module

The developed product has configuration controls for the well-designed and systematic operation of the e-module, so that users can easily access various links, images, videos, and read the text and tables contained in the e-module.

Research Subject

The research subject in this research and development is high school students in Pidie Regency SMA 1 Mutiara. The validity test process is carried out by material experts, media experts and biological education practitioners. Practicality tests are carried out by teachers and students. The population in this study is class X students of State High School Pidie Regency, Aceh Province. The sample in this study is class X students of SMAN 3 Unggul Sigli and SMAN 1 Mutiara for the 2022/2023 school year. The determination of the experimental group and the control group was determined by random sampling technique.

Place and Time of Research

The place of development research was carried out at Pidie Regency High School. This research was carried out in the 2021/2022 to 2022/2023 school year. The development was carried out in the odd semester of the 2022/2023 school year from February to June 2023. The implementation of the research was carried out in the Even semester of the 2022/2023 school year.

Research Data

The qualitative data in this study is data from the validation of the design of learning tools, AR e-modules and instruments to be used. This data is in the form of suggestions and comments from validators related

to the products developed. Quantitative data in this research and development consists of: 1) data on the validity of learning tools and AR e-module products, 2) data on the practicality of learning tools and AR e-module products, 3) data on the implementation of learning syntax, 3) *Data about pretest* and *Post Tests* digital literacy.

Research Instruments (Data Collection Instruments)

The validity test instrument consists of learning tool validation sheets, AR e-modules, learning syntax implementation questionnaires, student response questionnaires, practicality test instruments, digital *Literacy Pretest* and *Post Tests* questions, digital literacy questionnaires. The instrument will be validated by material experts, media experts, and biology education practitioners. The practicality test was carried out through a questionnaire to test the practicality of AR-assisted learning tools and e-modules by students in small group tests. The instruments used are questionnaires for the implementation of learning syntax and measurement of practicality tests. The effectiveness test was carried out through *pretest* and *posttest questions*. Digital literacy data was obtained through digital literacy questionnaires and digital literacy test answers. Syntax Implementation. The implementation of the syntax of the PBL learning model is carried out by observers through observation sheets of the application of syntax.

Data Analysis

Learning tools and AR e-modules are validated by material experts, media experts, and biology education practitioners, while practical results are obtained from student responses. The validity and practicality assessment was carried out based on the Likert scale with five answer options available in table 4.

Table 4. Likert Scale

Value	Information
5	Very precise / very clear / very precise
4	Appropriate/clear/quite appropriate
3	Quite precise/clear enough/quite precise
2	Not precise/less clear/less precise
1	Very inappropriate/unclear/inappropriate

Data from the validation of learning tools and AR e-modules was carried out with the following calculations:

$$\text{Validity Value} = \frac{\text{Assessment Result Value } \sigma}{\Sigma \text{ Item Questions}} \times 100\ \%$$

Data on the practicality of learning tools and AR e-modules are carried out with the following calculations:

$$\text{Practical Score} = \frac{\Sigma \text{ Assessment Results Value}}{\Sigma \text{ Item Questions}} \times 100\ \%$$

Table 5. Criteria for the Validity and Practicality of Learning Tools and AR E-modules

Range	Criteria
X = 100	Very valid/practical, can be used without revision
80 ≥ x < 100	Valid/practical, can be used with minor revisions
60 ≥ X < 80	Less valid/practical, recommended not to be used, moderate revision
40 ≥ X < 60	Invalid/practical, major revision, should not be used
20 ≥ x < 10	Highly invalid/practical, unusable, total revision

The effectiveness test was carried out based on the pretest and posttest n-gain test, digital literacy using the following formula:

$$g = \frac{S\ post - Spre}{S\ maks - Spre}$$

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Table 6. Categories N Gain Improvement	
Percentage (%)	**Category**
> 0,7	high
> 0,7 (g) > 0,3	medium
< 0,3	low

Digital literacy, and science literacy used tests of normality, homogeneity, linearity, correlation, and the average difference test of the two groups. The criteria for each test performed are shown in table 7.

Table 7. Criteria for Testing the Effectiveness of E-modules Using Statistical Analysis	
Types of Tests	**Criterion**
Normality	If the p-value is < α (0,05), then the data is not distributed normally If the p-value is > α (0,05), then the data is distributed normally
Homogeneity	If the p value is < α (0,05), then the data is not homogeneous If the p value is > α (0,05), then the data is homogeneous
ANCOVA	If the p value is ≤ α (0,05), then there is a difference in digital literacy, after learning with the AR e-module If the p value is > α (0,05), then there is no difference in digital literacy before and after studying with the AR e-module

The application of learning syntax is calculated based on the percentage of learning steps carried out from the results of the observation sheet. The implementation of the learning syntax is calculated using the following formula:

P = x 100 %

Information:

- P: Assessment results from observers
- A: Total score obtained
- B: Total ideal value

Table 8. Criteria for the Implementation of Learning Syntax	
Percentage (%)	**Criteria**
86-100	Very well executed
71-85	Good
56-70	Executed quite well
41-55	Poorly executed
25-40	Very poorly executed

RESULTS AND DISCUSSION

The results of the AR e-module N-Gain test based on local potential using the digital literacy PBL model in the control class on indicators (1) knowledge 0,30; (2) skills 0,27; (3) attitude 0,26; and (4) behavior 0,28. Overall, the results of the N-Gain test in the control class were in the low category (table 9). The results of the AR e-module N-Gain test based on local potential using the PBL model on digital literacy in the experimental class on indicators (1) knowledge 0,56; (2) skill 0,43; (3) attitude 0,54; and (4) behavior of 0,60. Overall, the results of the N-Gain learning test in the control class were in the medium category (table 9).

Table 9. Digital Literacy N-Gain Test Results			
Group	**Learning Indicators**	**N-Advantages**	**Level**
Control (PBL)	Knowledge	0,30	Medium
	Skills	0,27	Low
	Attitude	0,26	Low
	Behavior	0,28	Low
Experiment (A-module AR+PBL)	Knowledge	0,56	Medium
	Skills	0,43	Medium
	Attitude	0,54	Medium
	Behavior	0,60	Medium

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The normality test using the Kolmogorov-Smirnov single-sample test showed a p-value of all data > 0,05, which means that the students' digital literacy data was distributed normally (table 10). The homogeneity test uses the Levene test. The homogeneity test of the pretest of students' digital literacy was 0,115 and the posttest was 0,210. This shows that the data are homogeneous because the overall significant value > 0,05 (table 11).

Table 10. Normality Test Results

Group	Previous tests		Post tests	
	Sig Value.	Information	Sig Value.	Information
Control (PBL)	0,197	Normally	0,200	Normally
Treatment (E-Module AR+PBL)	0,200	Normally	0,200	Normally

Table 11. Homogeneity Test Results

	Sig Value.	Information
Previous tests	0,115	Homogeneous
Post tests	0,210	Homogeneous

The learning outcomes of digital literacy in the control class were (1) attitude 7,67; (2) behavior 13,37; (3) skills 22,24; and (4) knowledge of 22,04. The results of digital literacy learning in the experimental class were (1) attitude 17,02; (2) behavior 25,74; (3) skills 32,98; and (4) knowledge 39,72 (figure 2).

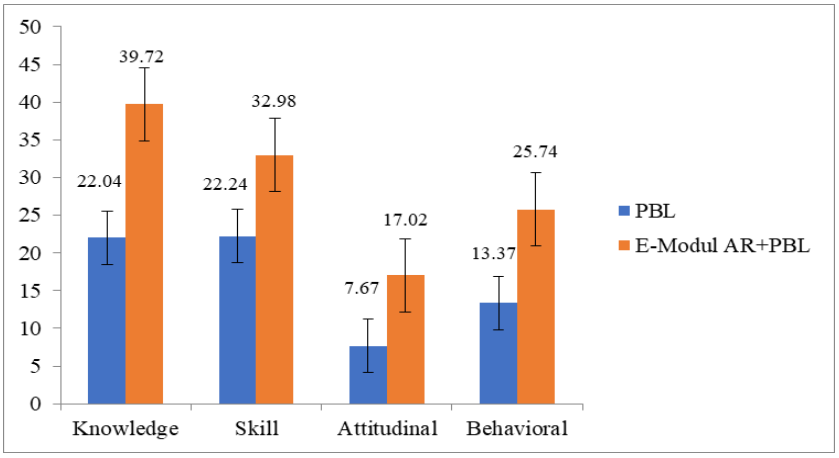

Figure 2. Student Digital Literacy Learning Outcomes

ANCOVA test of students' digital literacy obtained a significant value of 0,000 or a p value of <0,05, so it can be said that there is a difference in students' digital literacy in the control and treatment classes. A Partial Squared Eta value of 0,636 means that the AR-assisted e-module with the PBL model has an effect size of 63 % (table 13).

Table 12. Corrected Average

Variable	Group	Mean
Digital Literacy	Control (PBL)	68,465
	Treatment (E-Module AR + PBL)	78,877

Table 13. Digital Literacy ANCOVA Test Results Test Effects Between Subjects

Dependent Variable: Posttest						
Source	**Number of Type III Squares**	**Df**	**Square Average**	**F**	**Mr.**	**Partial Eta Squared**
Corrected Models	3003,913 people	2	1501,957	98,111	0,000	0,678
Intercept	4133,927	1	4133,927	270,037	0,000	0,744
To	1066,940	1	1066,940	69,695	0,000	0,428
Group	2487,249	1	2487,249	162,473	0,000	0,636
Error	1423,712	93	15,309			
Entire	523926,000	96				
Corrected Total	4427,625	95				
Note: R Squared = 0,678 (Adjusted R Squared = 0,672)						

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Students' responses to the AR e-module are carried out through the Student Response Sheet. The results of student responses to the AR e-module showed the attractiveness of the AR e-module by 92,3 %; ease of use of 90,9 %; ease of understanding by 90,9 %; and 90 % of the most recent sources. Overall, the results of the student response test to the AR e-module with a very good category (table 14).

Table 14. Results of Student Response Test to the AR e-Module

No.	Assessment Aspects	Student Response (%)	Level
1.	Kindness Tariq A-module R	92,3	Practical
2.	Ease of use	90,9	Practical
3.	Ease of understanding	90,9	Practical
4.	Latest sources	90	Practical
Average		91	Practical

The results of this study show that learning through AR-assisted e-modules using the PBL model has a better influence on students' digital literacy than PBL alone. This is because the e-module was developed with interactive AR technology and has been proven to improve students' digital literacy.

Students in the experimental class showed significant improvements in digital literacy in all indicators compared to the control class. Students in the care and control class use digital devices to search for and access information in learning. This activity encourages students to understand and apply digital concepts. Students in the care class showed a higher increase in digital knowledge compared to the control class. Students in the care class explore the material using the AR e-module. AR technology encourages students to be more active in learning.[46,47] Students are actively involved with digital technology thereby increasing a better understanding of digital concepts. Students in the control class rely only on limited text and images in understanding abstract concepts.

In addition to knowledge, students' digital skills also improved significantly in experimental classes. Through AR electronic modules, students can engage in digital navigation, applications, and manipulation of virtual objects.[48,49] This activity develops students' technical skills in using digital technology. In contrast, students in the control class showed a limited understanding of digital concepts. Students use textbooks and simple digital devices to explore the information needed in learning. Without the help of interactive AR technology, students engage in relatively static and less stimulating learning. [32] Students have difficulty visualizing concepts and developing digital skills. Students' digital literacy improvement is limited to the use of basic tools and techniques, without the added benefit of the rich and diverse learning environment available in AR e-modules. These activities involve less complex digital literacy skills, such as sophisticated digital navigation and manipulation of virtual objects.[50,51]

Active engagement with AR technology also has a positive impact on students' attitudes and behaviors towards digital learning.[4,52] Students in the nursing class showed a more enthusiastic attitude towards the use of technology in learning. More engaging and interactive AR technology improves student activity[53,54] to explore the learning content. In contrast, students in the control class showed more passive involvement and less enthusiasm due to technological limitations and interactivity in learning.

Overall, the integration of PBL with AR-assisted e-modules is more effective in improving digital literacy than PBL alone. When learning with AR electronic modules, using the PBL model allows students to apply science knowledge in real life and enhance an engaging and interactive learning experience with technology. AR technology allows students to actively interact with virtual content and engage in 3D simulations thereby increasing digital,[11,55,56] both in indicators of knowledge, skills, attitudes, and behavior.

CONCLUSIONS

This study aims to determine the effectiveness of AR-assisted e-modules in improving students' digital literacy in high school biology learning. The results showed that the corrected average score of digital literacy in the control class (68,465) was lower than the average score of digital literacy in the treatment class (78,877). Based on ANCOVA analysis, students' digital literacy obtained a significant score of 0,000 or a p value of <0,05, so it can be said that there is a difference in students' digital literacy in the control and treatment classes. This means that learning through AR-assisted e-modules using the PBL model has a better influence on students' digital literacy than PBL alone. Further research can be carried out by implementing AR-assisted e-modules at each school level to determine students' critical thinking skills, creativity, and learning outcomes.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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